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Final Report
Nonlinear Ocean Waves: Simulation, Chaos and Field Data
ONR: N00014-93-1-1009

PI: James H. Curry

Organization: University of Colorado
Applied Mathematics
Boulder, CO 80309-0526

Abstract:

The model of waves in shallow water that has been used describes nonlinear waves of permanent form, with two-dimensional surface patterns. These are the simplest waves that are not degenerate (i.e., not restricted to 1-dimension, not restricted to infinitesimal amplitudes, etc.). The work completed generalizes this model to the simplest waves that are nonlinear and have two-dimensional wave patterns and also have nontrivial time-dependence. This generalization is conceptually important because it allows descriptions of intrinsically time-dependent phenomena. The waves in question are typically not periodic in space or in time, and they have never been described before (in shallow water or in any other context).

RESULTS:
We have focused on two interrelated research topics in the context of nonlinear ocean waves:

Data Analysis:
(With Harvey Segur and Joe Hammack):

Among our most significant findings, currently in preparation for submission to Science, is our result that the nonlinear wave equation introduced by Kadomtsev and Petviashvili, the so called KP equation, has something important to say about real ocean waves and observed wave patterns in the near shore area. This is our conclusion based on an analysis of sensor data taken off of Duck North Carolina during the 1991 Halloween storm. (These data were provided to us by Dr. C. Long of the Duck facility.)

Our analysis leads us to the following conclusions: The KP equation can model some aspects of storm data, storm waves, some with amplitudes greater than 8 meters, in the near shore region exhibit a "groupiness" in structure, this groupiness can be modeled and the structure of the associated envelop can be predicted. And we believe that KP theory provides a better model than the traditional linear wave model.

Chaos:

Iterative methods for solving nonlinear equations, such as Newton's Method, generate noninvertible transformations. Such iterations are noninvertible because they have singularities, corresponding to algebraic sets, which can cause the iterations to exhibit unexpected behavior. Lora Billings and James Curry have discovered a, possibly, new type of bifurcation caused by the merging of stationary solutions to the equations of motion and points on the singular sets. This bifurcation is important because it leads to an unexpected change in the qualitative behavior of the convergence characteristic of the iteration method. Essentially, the iterative method gets "tangled" up and fails to converge. (We were lead to this problem because of a data fitting 'issue' that arose from our work on the KP equation.)